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# SUGGESTED CONDITIONS AND PROCEDURES FOR USING CARBON DIOXIDE TO CONTROL INSECTS IN GRAIN STORAGE FACILITIES

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# SUGGESTED CONDITIONS AND PROCEDURES FOR USING CARBON DIOXIDE TO CONTROL INSECTS IN GRAIN STORAGE FACILITIES

By Edward G. Jay[1]

## INTRODUCTION

The information contained in this report was derived from tests conducted by entomologists and their coworkers.[2] The report is not to be considered a final reference work on the application of carbon dioxide ($CO_2$) in grain storage facilities because more economical methods may be developed; however, it should serve as a guide to those who wish to use or further investigate this promising residue-free method of insect control.

Each storage facility will have its own peculiarities, which include areas to seal, access ports, and other factors pertaining to the application and distribution of the $CO_2$. Therefore, the information contained in this report is written for a general situation and does not pertain to any one type of storage facility. The information was gathered from research conducted in metal bins and concrete silos of 600- to 68,000- bushel capacities. The technique has not yet been tried in flat storage. Additional information on this promising control technique may be obtained from companies who sell $CO_2$ or by contacting the author directly.

## CONDITIONS AND CONCENTRATION LEVELS FOR APPLYING $CO_2$

### Temperature

The temperature of the grain should be above 70° F. during the application of the $CO_2$. Insects are active at higher temperatures, and thus their respiration rates are increased. This increases the effectiveness of the gas against the insects.

### Concentration of $CO_2$

If a $CO_2$ concentration of 60 percent is maintained for 4 days, it will kill most species and life stages of stored-product insects including larvae and pupae of the *Sitophilus* weevils and of the lesser grain borer, *Rhyzopertha dominica* (F.). Eggs and adults of several species of moths and beetles are killed in shorter exposure periods. When a storage facility is purged to this $CO_2$ concentration, the resulting oxygen concentration will be reduced from 21 percent to a concentration within the range of 7 to 10 percent.

If the $CO_2$ concentration of 60 percent cannot be attained and maintained for 4 days, a concentration of 45-percent $CO_2$ should be maintained for 5 to 6 days, or a concentration of 35-percent $CO_2$ should be maintained for 7 days. Concentrations above 60-percent $CO_2$ seem to have little added effect on the efficiency of the control method. Therefore, any attempts to maintain a concentration higher than this is a waste of $CO_2$.

### Bioassay

A method of determining if the $CO_2$ is effective is to observe the mortality of caged live insects held in the headspace or probed down into the grain mass during the treatment. Observed mortality of caged adult insects cannot be interpreted as evidence that all the insects in the grain were killed because the larvae and pupae of most insects, especially those living within the kernels, are harder to kill than the adults. However, this technique can be used as an indicator of the efficiency of the treatment.

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[2] The efforts of the following Market Quality Research Division personnel who assisted in various phases of this research are acknowledged: G.C. Pearman, A. Cagle, L.M. Redlinger, and H. Hall.

## SAFETY PRECAUTIONS

### Before Treatment

Appropriate warning signs should be placed outside of those areas where high $CO_2$ gas concentrations may accumulate. Suggested wording for such a sign is:

> "CAUTION - CARBON DIOXIDE GAS
> Ventilate before entering. A high $CO_2$ gas concentration may occur in this area. Carbon dioxide gas interferes with breathing, and its effects may be a hazard to life."

### During and After the Treatment

$CO_2$ comprises 0.03 percent of the earth's atmosphere and is indirectly the source of most of the carbon of the organic compounds of our body. The American Conference of Governmental Industrial Hygienists[3] has set a threshold limit value for humans of 5,000 p.p.m. of $CO_2$ or 0.5 percent based on a 5-day, 35-hour or 40-hour work week. Any $CO_2$ escaping from leaks in the equipment or facilities described here would, in most cases, blend into the atmosphere, and concentrations would quickly fall to within safe limits. Because $CO_2$ gas is 1-½ times as heavy as air, it tends to collect in unventilated areas, such as the working areas below silo complexes. Areas such as these should have air flowing through them during grain treatments with this gas.

$CO_2$ is the regulator of the breathing function in vertebrates. An increase in the $CO_2$ inhaled will cause an increased rate of breathing. A 2-percent concentration in air will cause a 50-percent increase in respiration; a 5-percent concentration will cause a laborious 300-percent increase in respiration.[4] Therefore, treated storage facilities should not be entered until after a sufficient time for the $CO_2$ gas to diffuse into the atmosphere. This time can be determined because analysis will show when less than 0.5 percent of $CO_2$ is present in the air.

If areas of high concentration of $CO_2$ must be entered, self-contained breathing apparatus must be used. *Do not use air-breathing or filter-type gas masks.* Concentrations of $CO_2$ in grain can be rapidly removed by running aeration fans, when present, or by turning the grain; but, if the grain is to remain in store for some time, it may be desirable to seal up the facility after treatment and allow the concentration of $CO_2$ to continue protecting the grain.

### Equipment

Because the $CO_2$ is delivered as a liquid and is stored in the tank at 300 p.s.i., it is advisable to use caution when working on the delivery tank in any area preceding the pressure regulator. Any work on the tank should be performed by a serviceman from the company from which the tank is leased.

## EQUIPMENT

### Application of $CO_2$

The tank of liquid $CO_2$ should be obtained from a distributor. The size of the tank will depend on the amount of $CO_2$ to be used and the delivery schedule. Currently, 2-, 4-, and 6-ton tanks are available. The tank normally will be equipped with refrigeration to prevent the liquid $CO_2$ from attaining too great a pressure and with a small vaporizer to produce gas upon demand. For treatment of grain, the small, built-in vaporizer is not adequate for initial purges of large silos, elevators, or tanks but will be adequate for subsequent treatments to maintain the desired concentration of $CO_2$. The built-in vaporizer should be adequate for the initial purge and subsequent treatments of small (500 to 10,000 bushels) storage facilities. An external vaporizer will be required for the initial purge of large storage facilities. It is desirable to have two 57-ampere vaporizers, which are similar to heaters, each capable of converting 600 pounds of liquid $CO_2$ to gas per hour. If adequate electrical power or equipment is not available, one vaporizer of this size should be adequate for most applications. A pressure regulator should be attached to the final outlet of the $CO_2$ tank to reduce the tank pressure (normally 300 p.s.i.) to 100 to 125 p.s.i. A regulating valve (globe value) should be in the line after the pressure regulator to maintain the desired flow rate. A good quality 3/4-inch inside diameter rubber garden hose may be used to introduce the $CO_2$ into the storage facility. Rubber hose is more flexible than plastic hose at reduced temperatures and, therefore, more desirable. The hose should be long enough to reach into the headspace of the facility and should be attached to the tank at the regulating valve.

Initial installation of the $CO_2$ tank vaporizers and other equipment usually will be made by a serviceman or engineer from the company contracted to supply the $CO_2$. The tank is filled from a large trailer truck capable of carrying about 30,000 pounds of liquid $CO_2$.

[3] American Conference of Governmental Industrial Hygienists. Threshold limit values of airborne contaminants. Adopted by ACGIH for 1969 and intended changes. 28 pp. 1969.

[4] Anonymous. Matheson Gas Data Book. Ed. 4,500 pp. The Matheson Company, Inc. East Rutherford, N.J. 1966.

### Monitoring $CO_2$ Concentration

Several techniques are available for monitoring $CO_2$ concentrations. All involve getting a sample of the air-$CO_2$ mixture from the storage facility into the monitoring device. A piece of flexible tubing, such as 1/4-inch Tygon, run just under the surface of the grain in the storage facility and another small probe driven deep into the grain is the most simplified form of monitoring the $CO_2$ concentration.

If unusually large amounts of dust and other foreign material are present under the fill spout, a probe should be inserted into this material because this will be the hardest area to penetrate with the $CO_2$ gas. Deep probes can be constructed of pieces of 1/4-inch galvanized water pipe coupled together to achieve the desired length. Flexible tubing may be used to connect these deep probes with the monitor. Flexible tubing may also be used as sampling probes if installed in the storage facility before filling. The walls of this tubing should be rigid so that they do not collapse under the pressure from the grain. A tip should be placed on each probe end to prevent entry of foreign matter. "Double-check" probes (H.T. McGill Co., Houston, Tex.) may be purchased for this use, or a probe tip with slits on the side for gas entry may be fabricated.

Other probes may be placed throughout the grain mass to monitor the distribution and concentration of the gas. However, it has been found that the gas generally distributes itself evenly throughout the grain mass during the later stages of the initial purge with the exception of the areas having much foreign material. The probe just under the surface of the grain mass is important because the $CO_2$ concentration will usually start to decrease here first. This probe should not be placed near the nozzle(s) of the application hose. Further use of this sampling probe follows.

Basically, three types of units can be used to monitor the atmosphere in the storage facility. Also, a small vacuum pump, such as the Bantam Dyna-Vac model 7062 (Cole-Parmer, Chicago, Ill.), will be needed to draw the gas sample for analysis in some of the following applications. The three basic types of monitoring equipment are:

1. A Fyrite $CO_2$ indicator (for 0 to 60-percent $CO_2$ available from Fisher Scientific Co., Pittsburgh, Pa., presently sells for less than $100). This may be used with its own hand pump to monitor the $CO_2$ concentration from the tube just under the surface of the grain. A small vacuum pump will be needed to collect samples from probes placed in the grain mass.

2. A small, portable $CO_2$ sampling unit with a meter that reads out directly in percentage of $CO_2$ in the atmosphere. This unit is now under development by the Gow-Mac Instrument Corp., Madison, N.J. This unit will have a self-contained vacuum pump and will be battery operated. The vacuum pump in this unit should be adequate for pulling samples from probes in the grain mass.

3. A Fisher model 25V gas partitioner or a Fisher-Hamilton model 29 gas partitioner (presently at $600 to $1,000). These units will also analyze for oxygen and nitrogen in the sample. Other equipment necessary to place this equipment in operation will cost several hundred dollars. Therefore, this system should only be considered by applicators who plan to run a large number of gas samples and wish to obtain a high degree of accuracy.

## STORAGE FACILITY PREPARATION

### Sealing

All areas where $CO_2$ might escape on all types of storage facilities, such as fill spouts, emptying chutes, and manholes, should be sealed with duct tape (obtainable from refrigeration or air-conditioning supply houses) before introducing the $CO_2$. Similarly, cross-aeration ducts in concrete silos should be sealed with taped-on polyethylene film or plywood. This may necessitate turning enough grain so that access may be gained. The cap on round or square metal bins should be sealed with duct tape or caulking compound before applying $CO_2$.

Application of this gas creates a positive pressure in a storage facility that must be relieved (discussed below). If the facility is equipped with an aeration duct or a fan, or both, this is a good place to relieve the pressure. After the initial purging, when the concentration is reached, this area should be sealed off.

### Installation of $CO_2$ Input Hose Into Storage Facility

A piece of plywood cut to fit any convenient access area can be drilled to allow the input hose to be inserted into the headspace. The hose should be attached to a structural cross member, if present, so that the $CO_2$ is delivered onto the grain mass. The hose should be supported in a semirigid manner in other types of storage facilities. The hose nozzle should be at least 3 feet above the grain surface. It is desirable to "T" off of the host nozzle with two short pieces of hose, so that better distribution of the gas can be obtained over and down into the grain. "T's" can be obtained at most garden supply outlets.

The gas sampling lines can be accommodated by holes drilled in the piece of plywood cut to fit an access port in the headspace. This piece of plywood should be taped to the top of the port with duct tape.

## Pressure

During the initial purging of the storage facility, pressure will build up because of the large initial volume of gas applied. Some method must be used to relieve this pressure. If the storage facility has an aeration duct at the bottom, it can be left open during the initial purge to relieve the pressure. If the storage facility is not so equipped, a small opening can be provided at an access door during the initial purge to relieve the pressure. The area left open can be sealed after the initial purge. (See "Starting the Purge.")

## Calculation of Theoretical Amount of Gas to be Used in Initial Purge

The following formula can be used to estimate the free air space to be purged in a bin having a flat top: Number of bushels of commodity x 1.24 x A + B = cubic feet of free air space

A = approximate percentage of free interkernel air space in the commodity, that is, soybeans, 35 percent; grain sorghum, 37 percent; rice and shelled corn, 40 percent; wheat, 46 percent; barley, 50 percent; and oats, 58 percent.

B = cubic feet of free air space in the headspace above the commodity determined by 3.14 $r^2h$ (r = radius and h = height) for cylindrical volumes.

Sample calculation: A concrete silo measuring 81 by 24 feet contains 27,500 bushels of wheat. Headspace is about 10 feet.

27,500 x 1.24 x 0.40 + (3.14 x $12^2$ x 10) = 18,161 cubic feet. One pound of liquid $CO_2$ produces 8.72 cubic feet of gas; therefore, 2,083 pounds of $CO_2$ theoretically should purge the atmosphere of the storage facility to 100-percent $CO_2$. However, due to the mixing of the $CO_2$ with the atmosphere in the storage facility and due to the difficulty encountered in penetrating the grain mass, this amount of $CO_2$ will not produce a 100-percent concentration. The necessity of relieving pressure on the storage facility, especially when no pressure relief, such as an aeration fan duct, is available at the bottom of the storage facility also contributes to loss of $CO_2$. However, this formula will provide a good indication of how much $CO_2$ will be used in the initial purge.

## Starting the Purge

After calculating and obtaining the theoretical amount of $CO_2$ needed, the initial purge can be started. The external vaporizer(s) should be preset to maintain the gas at a temperature of 60° to 90° F.—the faster the flow rate, the more the vaporizer(s) will operate, and at high flow rates some reduction in temperature may occur. The regulating valve should be opened to start the gas flow. Initially, personnel should be stationed near the areas where $CO_2$ is applied and where pressure is to be released from the storage facility to ascertain if the flow rate is too high. Some indicators that the flow rate is too high are:

1. Grain in headspace displaced by gas flow.
2. Duct tape loosened around seals.
3. Excessive airflow around or through the pressure relief area(s). (Some experience is needed to be able to use this factor.)

The initial flow rate for purging will be a function of the capacity of the storage facility, the output of the vaporizer(s), and the ability to relieve pressure. Our experience has shown that in a concrete silo of 20,000-bushel capacity the initial purge rate should be at 300 to 400 pounds of $CO_2$ per hour, and one having a 30,000-bushel capacity should be purged at 500 to 600 pounds of $CO_2$ per hour.

## Gas Sampling During the Purge

Analysis of the air should begin when about 25 percent of the calculated amount has been delivered into the storage facility. In the simplest application, the gage built into the supply tank can be used to measure the amount applied. To determine its accuracy, this gage should be checked against the one on the supply truck during the filling operation. Uneven distribution of the $CO_2$ can be expected during the early stages of the purge because of different pressures arising as the air in the storage facility is displaced and because of the difficulty in penetrating foreign materials mixed in the grain. The $CO_2$ will distribute itself evenly throughout the grain mass during the later phases of the purge. Once the desired concentration is reached, as indicated by analysis of the storage atmosphere, the gas flow can be reduced or shut off.

## Gas Sampling and Application After the Purge

After the desired concentration is reached, gas sampling can be limited to the sample tube run just under the surface of the grain. Because $CO_2$ is heavier than air, the initial loss will occur in this area. When the concentration falls below that desired, more $CO_2$ can be applied to bring it back to the desired level. An alternative procedure is to allow the gas to flow in constantly at a low rate to compensate for leaks and loss in the upper areas of the headspace. If additional facilities are to be purged while the atmosphere is maintained in others, a "T" or "T's" and regulating valves should be installed between the pressure regulator and the additional delivery hoses. Once the personnel become familiar with the application of $CO_2$ into their particular storage facilities, they should not have any difficulty maintaining the concentration after the initial purge. This can be accomplished with minimal labor and equipment.

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